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DOES SURGICAL TREATMENT OF FEMORAL NECK FRACTURE INCREASE THE RISK OF FEMORAL HEAD COLLAPSE?

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Introduction

Femoral head collapse is a possible complication after surgical treatment of femoral neck fractures. The purpose of this study was to examine whether implantation of a Sliding Hip Screw (SHS) or an X-Bolt could increase the risk of femoral head collapse. Similar to traditional hip screws, the X-Bolt is implanted through the femoral neck; however, it uses an expanding cross-shape to improve rotational stability. The risk of collapse was investigated alongside patient factors.

Materials & Methods

This numerical study assessed the risk of femoral head collapse using linear eigenvalue buckling (an established method [1]), and also from the maximum principal strain within the cortical bone. The femoral head was loaded using the pressures reported by Yoshida et al. for a patient sitting down (reported to put the femoral head at greatest risk of collapse [2]), with a peak pressure of 9.4 MPa and an average pressure of 1.59 MPa.

The femur was fixed in all degrees of freedom at a plane through the femoral neck (Fig 1). The X-Bolt and SHS were implanted in accordance with the operative techniques. The femoral head and implants were meshed with quadratic tetrahedral elements, and cortical bone was meshed with triangular thin shell elements. A converged mesh seeding density of 1.2 mm was used. All models were create and solved using ABAQUS finite element software (version 6.12, Simulia, Dassault Systèmes, France).

The influence of implant type and presence (termed the 'Implant' models, comprising No Implant, X-Bolt, and SHS) was examined alongside the following patient factors:

- Cortical thickness (1 mm, 2 mm, and 3 mm)
- Cortical modulus (1 GPa, 4 GPa and 7 GPa)
- Necrotic modulus (1 MPa to 500 MPa), modelled as a cone of bone of 60 ° angle (Fig 1)
- Necrotic Cone Angle (20°, 40°, 60° and 80°)
- Head diameter (38.0 mm, 42.2 mm, 48.4 mm, 53.6 mm)

This resulted in nineteen cases which were run for each implant condition (No Implant, X-Bolt, and SHS), resulting in a total of 57 models. The finite element models were validated using experimental tests (Fig 1b) performed on five 4th generation composite Sawbones femurs (Malmö, Sweden), and verified against previously published results [1].

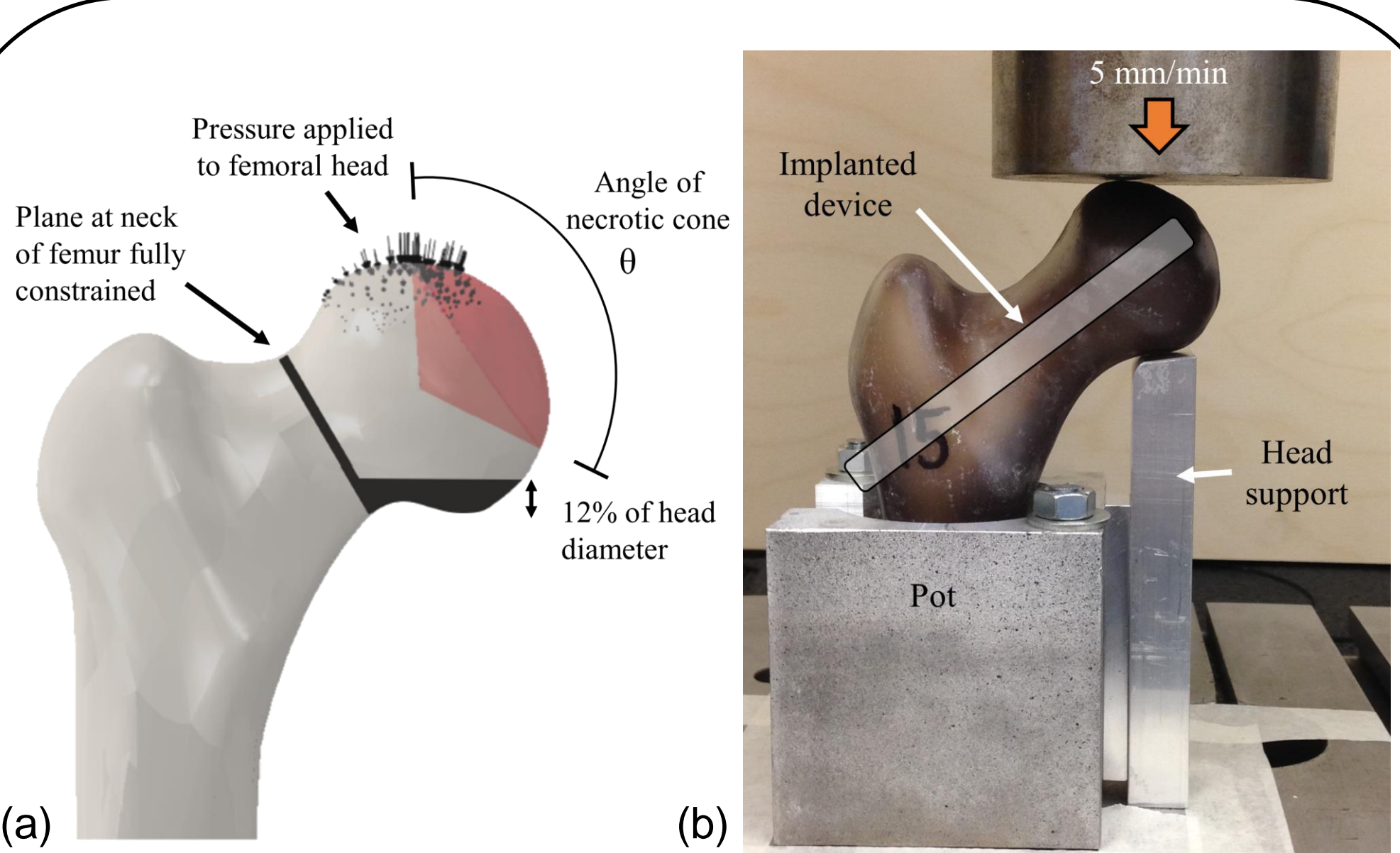


Fig 1: Illustration of (a) the finite element model setup, and (b) the setup used for the experimental validation tests on Sawbone femurs.

Results

The Kruskal Wallis test found no significant differences between the Implant groups. Of the patient factors examined, only changes in necrotic modulus of the femoral head caused a significant increase in the risk of femoral head collapse, for both buckling and tensile strain results (Table 1); risk was greatly increased when the necrotic modulus was below 100 MPa (Fig 2). Strain was greatly increased in the anterior region of the femoral head in the necrotic model (Fig 3).

Table 1: Results of the Kruskal Wallis statistical tests for maximum principal strain

Model	Chi-squared	p-value	Significance
Implant	1.0603	0.589	-
Cortical Thickness	0.43087	0.8062	-
Cortical Modulus	6.1292	0.0467	*
Necrotic Modulus	33.901	<0.001	***
Necrotic Cone Angle	6.2844	0.0986	-
Head Diameter	8.4262	0.0772	-

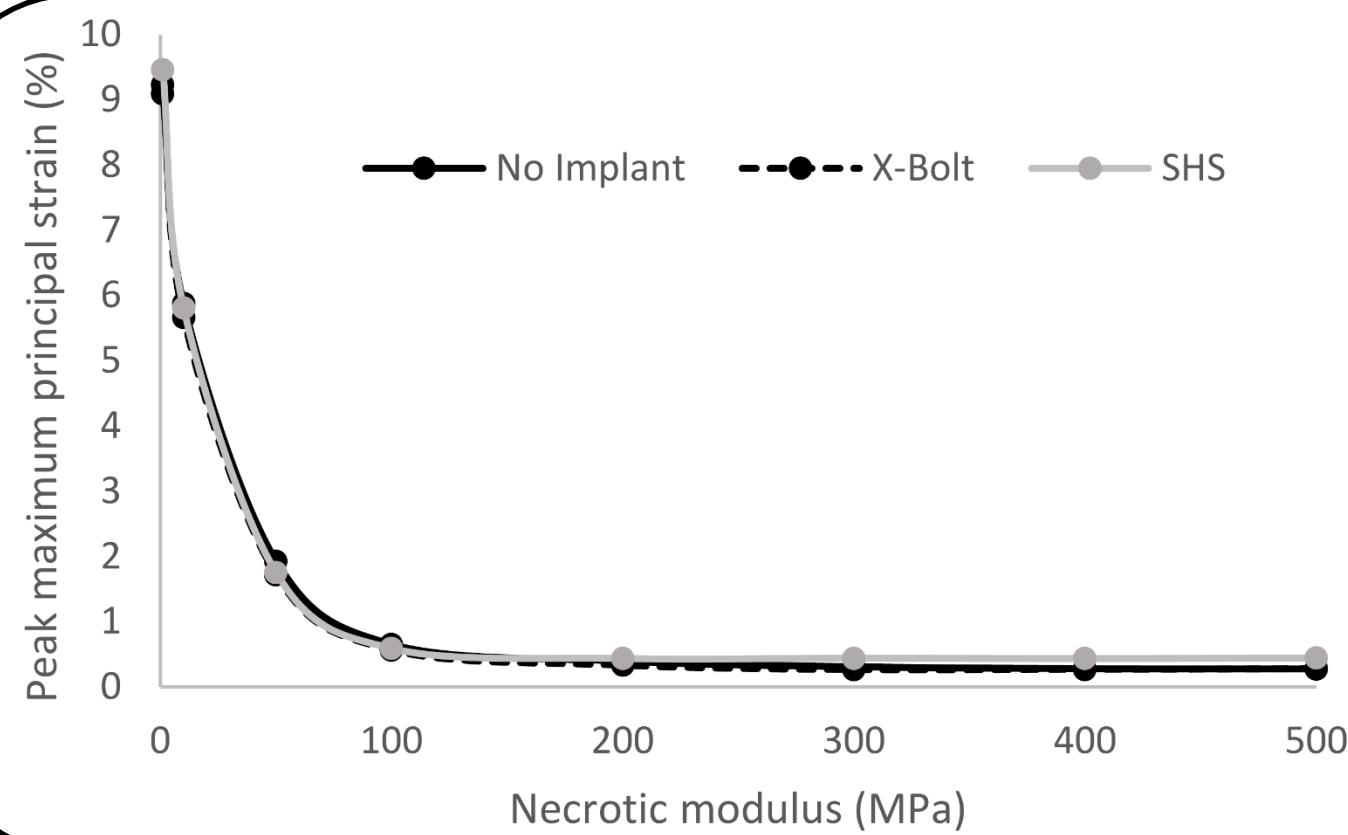
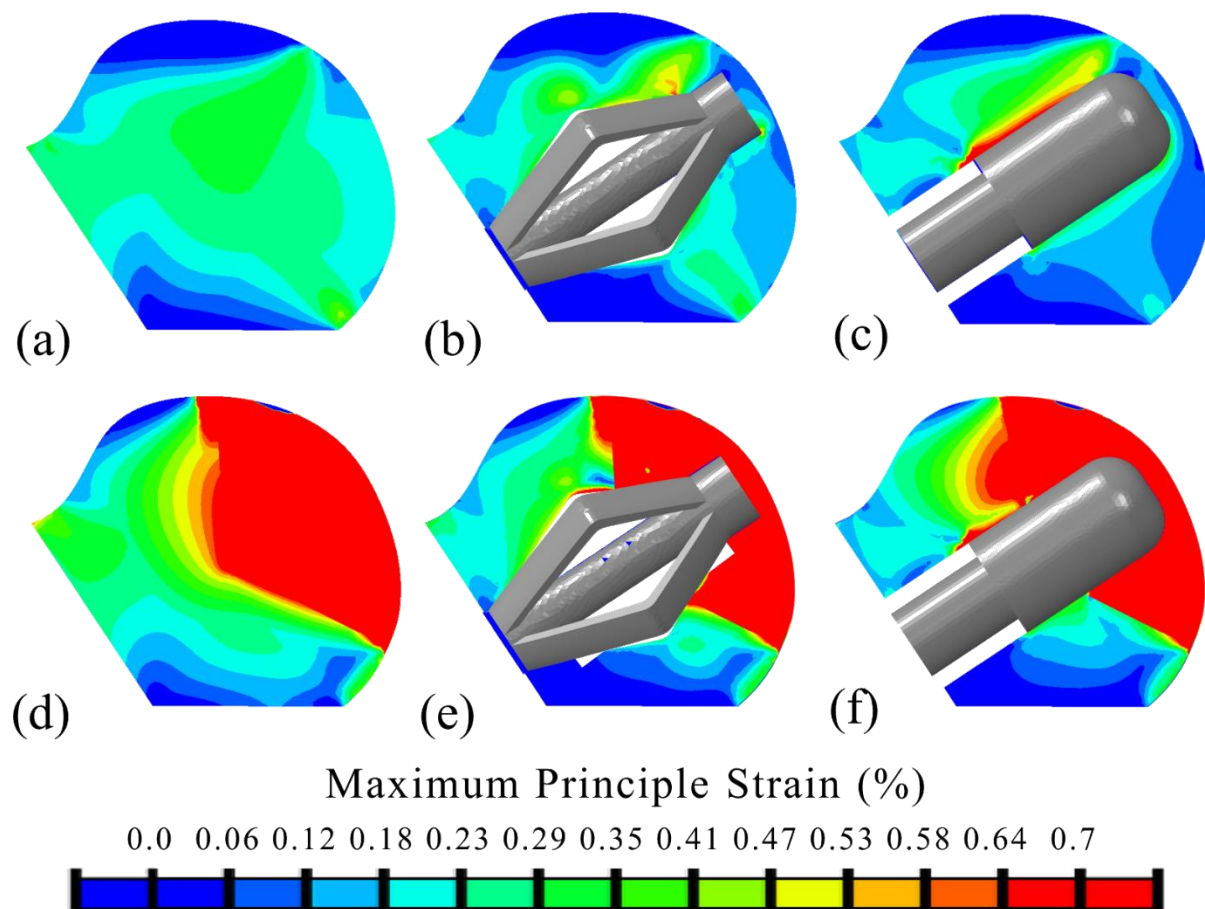


Fig 2: Illustration of the inversely proportional relationship between necrotic modulus and peak maximum principal strain.

Fig 3: Maximum principal strain distribution within the femoral head for the healthy bone (a-c) and necrotic bone (1 MPa) (d-f).



Discussion

The results of the present study demonstrate that deterioration of the cancellous bone underneath the cortical shell can greatly increase the risk of femoral head collapse, which supports the findings of Volokh et al. [1]. Importantly, the presence of either an X-Bolt or SHS implant appeared to have no influence on the risk of femoral head collapse.

References

- [1] Volokh, K. Y. et al. "Prediction of femoral head collapse in osteonecrosis." (2006) J Biomech Eng 128, p467-470.
- [2] Yoshida, H. et al. "Three-dimensional hip contact area and pressure distribution during activities of daily living" (2005) J Biomech 39, p1996-2004.

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